A Regional Modeling Structure for Assessing Costs of Implementing Manure Nutrient Standards: Application to the Chesapeake Bay Watershed

Marcel Aillery
Noel Gollehon
Marc Ribaudo

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Abstract:
A Chesapeake Bay Watershed manure management model estimates the minimal regional net cost of land applying manure at $76 million under a multi-year phosphorus standard, with assumed manure acceptance rate on 60 percent of cropland. The multi-year standard represents a savings of 17 percent relative to an annual phosphorus standard.

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The authors are agricultural economists in the Resource Economics Division, Economic Research Service, USDA. E-mail: maillery@ers.usda.gov, Postal address: Marcel Aillery, ERS-PMT, Rm.S-4037, 1800 M Street NW, Washington, D.C. 20036-5831. The views expressed are the authors' and do not necessarily represent policies or views of ERS or the U.S. Department of Agriculture.

Introduction

Public attention has focused increasingly on the concentration of animal waste and resulting potential impacts on water quality, aquatic resources, and public health. In 2003, EPA issued new regulations for the National Pollutant Discharge Elimination System (NPDES) Permit Regulation and Effluent Limitations Guidelines (ELGs) and Standards for Concentrated Animal Feeding Operations (CAFOs) to reduce potential impacts (U.S. EPA, 2003). The rules will affect an estimated 15,500 CAFOs, including 11,000 of the largest Animal Feeding Operations (AFOs) and 4,500 medium-sized AFOs with direct surface water contact. CAFOs will need a point-source discharge permit to meet the requirements of the permit (U.S. EPA, 2003). The rule requires development and adoption of site-specific nutrient management plans to ensure that animal manure is used consistent with proper agriculture practices that protect water quality.

USDA has a stated goal that all AFOs develop and implement technically sound, economically feasible, and site-specific Comprehensive Nutrient Management Plans (CNMPs). Achieving this goal will minimize potential water pollutants from confined animal facilities and land application of manure (USDA, 2000). Of more than 250,000 operations needing a CNMP nationally, roughly 8,600 are targeted for completion under current funding levels for FY2003 (USDA, 2002).

Land application of manure nutrients at rates not exceeding crop uptake is a primary emphasis of both the new EPA regulations and USDA policies for manure management. A proper manure application rate is the single most important management consideration to avoid the potential contamination of water resources by manure nutrients (Mulla et al., 1999). However, land application of manure at agronomic rates will impose costs on many animal producers. The emphasis on land application based on nutrient standards represents a new challenge to large livestock and poultry operations, particularly in areas with high concentrations of confined animal production relative to the cropland and pastureland base.

In this paper, we present a regional model of manure management for the Chesapeake Bay Watershed (Figure 1). The Chesapeake Bay Watershed (CBW) encompasses several multi-county areas where manure-nutrient production from confined animal operations exceeds the capacity of cropland to utilize manure nutrients when applied at agronomic rates (Gollehon, et al., 2001). Where manure produced exceeds local use potential, manure may have to be transported substantial distances to access spreadable land under a land-based management strategy. We apply our model to assess the total cost of meeting land application policy goals for manure produced in the CBW, subject to assimilative capacity of cropland and pastureland, the implementation of nutrient standards, and the share of manure utilized in non-landbased applications. Empirical analysis in this paper focuses on alternative specifications of a phosphorus-based nutrient standard, and implications for producer costs in the CBW.

Implementation of manure-nutrient standards

The USDA's Natural Resources Conservation Service (NRCS) has developed a conservation policy for nutrient management that addresses requirements for land application of manure nutrients. Land application is often the preferred method of utilizing manure as manure-nutrients can supply a large share of nutrients required for crop growth, thereby reducing the need for commercial fertilizers. Manure also provides organic matter, improving soil tilth and moisture-holding capacity. NRCS nutrient management criteria for animal feeding operations are implemented through development and implementation of site-specific nutrient management plans, as defined in the NRCS General Manual, Title 190, Part 402, and the NRCS Conservation

Practice Standard, Nutrient Management (Code 590). These policy documents specify that nutrient land application rates be based upon Land Grant University nutrient application recommendations.

Under the NRCS policy, manure application rates may be based on either a nitrogen (N) or phosphorus (P) standard. Manure application rates based on an N standard would meet, but not exceed, nitrogen recommendations for the crop. However, given the ratio of nitrogen to phosphorus in manure, use of the N standard will generally result in phosphorus applications that exceed annual P requirements of the crop. NRCS policy permits use of the N standard on crop fields where additional phosphorus is recommended, or where the risk for off-site transport is deemed acceptable. (The Phosphorus Index is currently the most widely used risk assessment tool for this purpose.)

Under current policy, farms with access to adequate land for manure spreading may apply phosphorus equal to the amount of phosphorus contained in the biomass of multiple years of crops grown on the site, provided that the nitrogen recommendation for crops grown is not exceeded. Multi-year phosphorus applications reduce field operation costs for a given quantity of manure. Farms that utilize this approach must have sufficient land to rotate manure applications among fields so that a given site receives manure infrequently and excessive soil-phosphorus accumulation is avoided (USDA, 2000).

Manure application rates that are based on an annual P standard supply only the amount of phosphorus that is recommended over a growing season, based on either current soil tests or calculated as a function of the phosphorus content of plant biomass removed at harvest. Manure applied based on an annual P standard will not usually supply the recommended amount of nitrogen, necessitating the application of additional N from other sources. Applying manure at an annual phosphorus removal rate is most likely to be required on animal operations where land is limited, soil P levels are high, or runoff risks are significant.

Methods

A least-cost optimization framework developed for the CBW is used to assess potential costs to the animal sector of federal policies governing manure land application. The modeling framework allocates total manure produced—less tonnage currently used in industrial applications—across cropland and pastureland in the CBW. Key factors affecting the distribution of land-applied manure include per-unit hauling and application costs by manure type, the spatial relationship of manure sources to spreadable land, the nutrient assimilative capacity of the landbase and willingness of landowners to accept manure, and required nutrient standards for manure application.

For purposes of the modeling analysis, the range of potential costs of nutrient standards may be defined by two scenarios: 1) manure applied at an N standard rate for all farms, and 2) manure applied at a P standard rate for all farms. Neither is intended to reflect expected implementation strategies, as some farms will meet criteria for an N-standard rate and others will be required to adopt the more restrictive P-standard rates. In the Chesapeake Bay regional analysis, we did not have the data on soil characteristics and historical land use to determine the share of land at a county level that would be required to meet an N or P standard. Thus, the two scenarios used in the present study are intended to establish upper and lower bounds on the costs associated with implementing nutrient management plans.

In the empirical analysis developed for this paper, we consider the effect of two alternative implementation strategies for a phosphorus standard: 1) the annual P standard, where manure-P applied equals the annual crop P requirements, and 2) a multiple-year P standard that provides for manure-P applications in excess of annual crop requirements on a rotational basis, as permitted by NRCS under certain soil conditions. The cost effects of alternative implementation strategies for the P standard are evaluated relative to an N standard. Table 1 highlights attributes and cost factors by nutrient standard.

In general, an N standard permits a higher manure application per acre than a P standard, as the ratio of N crop uptake to N manure content generally exceeds the corresponding ratio for manure P. As a result, substantially greater acreage is required to spread a given tonnage of manure under a P standard, with a commensurate increase in hauling costs required to access available spreadable acreage. The multi-year P standard, where permitted, will help to offset the increase in costs for producers having to meet a P standard for applied manure.

For purposes of this analysis, field application costs for manure spreading are calculated on a tonnage basis, consistent with available cost data. Thus, reported aggregate field application costs are equivalent across N and P standards where total tonnage applied is equivalent. However, manure incorporation costs are specified on a per-acre basis, and increase with the level of acres treated. Therefore, aggregate costs of manure incorporation are higher under an annual P standard due to expanded acres treated for a given tonnage applied.

Fertilizer cost savings include 1) savings from reduced purchase of commercial fertilizer and 2) savings from reduced use of machinery to apply commercial fertilizer. The cost savings apply only to that portion of manure-nutrients that are used by the crop that can be assumed to offset commercial fertilizer purchases. Under an N standard, manure provides the full nutrient requirements for all acres treated; thus, no additional chemical fertilizer is assumed to be required. 'Savings' on commercial fertilizer are computed based on all manure N applied and that share of manure P that is actually used by the crop. In addition, it is assumed that no equipment passes are required for chemical fertilizer application, resulting in full savings in fertilizer application costs. Under an annual P standard, manure-nutrients are fully utilized by the crop and thus all manure-nutrients represent a 'savings' on commercial fertilizer costs. However, manure applied at an annual P standard fails to provide the full nitrogen requirement of the crop, and supplemental N will be required. As equipment passes will be required to supply supplemental commercial N fertilizer, we assume no savings to reduced equipment use.

The multi-year P standard permitted by NRCS under most soil conditions modifies cost and savings impacts under the annual P standard. The multi-year P standard permits manure application rates equivalent to an N standard, but only on treated acres (acres with applied manure in a given year) within the multi-year acreage rotation receiving manure ('receiving acres') under an annual P standard. Thus, manure is applied once in a multi-year period, and crops draw from manure applied P over several years. The costs of manure transport and application are equivalent to those reported under an annual P standard, as the same quantity of manure is land applied. However, incorporation costs are incurred only on acres treated (equal to the N standard). Cost savings from reduced purchase of commercial fertilizer are equivalent to the annual P standard, as manure nutrients are fully utilized in crop production over the rotation. Cost savings from reduced use of machinery to apply fertilizer, however, are greater than under the annual P standard since full nutrient requirements are supplied on acres treated in a given year and no further applications are assumed necessary on that share of acreage.

Modeling Manure Management in the Chesapeake Bay Watershed

A regional modeling framework was developed by ERS researchers to evaluate the costs of animal-waste management policies in the Chesapeake Bay watershed. The model is designed to minimize the total regional costs of manure management, transport, and application for use on agricultural lands in the CBW, given the existing structure and scale of the animal industry and current manure-storage technologies in use. The model provides an analytic framework to 1) track manure and related nutrient flows within the basin, from AFOs to site application and use, 2) compute the regional costs of land applying manure, given least-cost manure transfers within the basin; and 3) evaluate alternative land-application regulations and nutrient management policies. The regional model specification captures the critical element of competition for land on which to spread manure in areas with significant animal concentrations by endogenizing access to land and associated hauling costs.

Model data

Two primary data sources form the basis of the model data set: the 1997 Census of Agriculture and the National Land Cover Dataset from USGS. Farm-level Census data were used to generate county-level measures of animal operations and animal-units, total manure production, excess recoverable manure, manure-nutrient content, and potential assimilative capacity of the land for applied manure nutrients. The National Land Cover Dataset was used to define the spatial pattern of land available for manure spreading and to simulate the spatial distribution of animal operations.

Agricultural Census. Our analysis uses the farm balance of manure nutrient production relative to the farm's potential to utilize nutrients for crop production, based on farm-level data collected for the 1997 Census of Agriculture. Results from the farm-level calculations are then summed across animal types and aggregated at the county level.[1] From farm-level data, we used crop acres and crop production levels to determine potential manure nutrient use for crops specific to confined-animal producers (procedures in Kellogg, et al. (2000)).

Computation of manure nutrients, potential manure nutrient use by farms with animals, and potential assimilative capacity of farms without confined animals were computed following procedures in Gollehon, et al. (2001) and Kellogg, et al. (2000). Briefly, manure nutrients were estimated from Census reported end-of-year inventory and annual sales data and coefficients of manure production by animal type. Potentials for manure nutrient use were estimated based on reported yields and acres of 24 major field crops and permanent pasture.

National Land Cover Dataset. To assess availability and spatial pattern of spreadable land for manure application, the analysis uses the National Land Cover Dataset developed by the U.S. Geological Survey. This dataset is based on 1992 Landsat thematic mapper imagery at 30-meter resolution, classified into 21 landuse categories. By combining the crop and pasture categories, we were able to assemble a maximum spreadable land base for all counties in the study region.

GIS Data. To estimate hauling distance requirements for spreading manure, a Geographic Information System (GIS) is used to create "area-to-distance" functions for each county and manure-producing farm in the study region. These functions are a central component of the optimization model, linking the area needed for manure spreading with the distance farmers would be required to travel to dispose of excess manure. Distance functions reflect 1) the spatial pattern of spreadable land; 2) the number of farms competing for spreadable land; and 3) the location of animal operations relative to spreadable land.

Area-to-distance functions for within-county transfers represent the average distance from all farms in a given county to spreadable land within that county. With limited amounts of excess manure, spreadable land is relatively accessible and hauling distances are generally short.

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1 Our analysis meets all respondent confidentiality requirements of the published Census of Agriculture values.

As manure spreading requirements increase, animal operations must compete increasingly for the same acreage—reducing accessibility and increasing the distance needed to access available acreage.[2] The relationship between the spreadable acreage requirement and average distance hauled is upward sloping and fairly linear along much of the observed range.

Out-of-county functions represent hauling distances from animal operations in a source county to spreadable acreage in adjacent counties. Each out-of-county function is unique, reflecting estimated distance from the source-county animal farm and the spatial pattern of spreadable land in the destination county, as encountered from the direction of the source county. A two-stage process was used to generate the average distance functions. First, an intercept term is calculated, representing the distance from each farm in a source county to the edge of spreadable acreage in a destination county. Second, the slope of the distance function is estimated, representing the hauling distance required within the destination county for a given area of spreadable acreage, measured from the direction of the source county. Thus, out-of-county hauling functions combine a source-to-destination county intercept and slope coefficient for the area-to-distance relationship for destination counties.

To integrate the GIS data into a format for the optimization model, regression coefficients were compiled for each of the area-to-distance functions. A single set of coefficients was produced for within-county functions by modeled county. For out-of-county functions, separate coefficients were generated for each source farm and destination county combination within an assumed 60-km radius. The radius for the 16 counties with the largest quantities of excess manure was expanded to 150-km (93-miles), reflecting the potentially greater hauling distances required from counties where animal production is concentrated. To reduce the number of

2 The actual area of available spreadable acreage used for manure application in a given county is determined by the optimization model, reflecting manure flows within and across counties that minimize disposal costs, subject to

manure source and destination combinations, animal farms were aggregated (binned) by 12-km grid across the watershed area. Although the binning procedure reduces the precision of the intercepts for inter-county functions, this was necessary for tractability of the optimization problem. In addition, functions estimated from the GIS were linearized for modeling purposes by truncating the upper and lower tails of the distribution (10 percent of acreage) and fitting a linear function to the mid-range observations (80 percent). The use of linear representations reflects the high computer memory requirements for non-linear distance functions, and the fact that observed functions were very nearly linear over the relevant mid-range.

Regional model structure

The county serves as the primary modeling unit for the regional model. The county-level specification provides consistency with Census data and other county-level data, while permitting differentiation of institutions and regulatory conditions across county and State political boundaries within the watershed. Manure is produced in a ‘source county’ and land-applied (or otherwise disposed of) in a ‘destination county’. ‘Model’ counties include all non-municipality counties within the watershed with agricultural land. The full watershed model includes 160 model counties, representing potential ‘source’ and ‘destination’ counties. ‘Sink’ counties refer to ‘destination’ counties outside the modeled area that serve as a potential sink for manure from ‘model’ counties, subject to net assimilative capacity after accounting for in-county manure applications. There are 104 sink counties included in the full watershed model, comprising non-municipality counties within 60 kilometers (37 miles) of a ‘model’ county (measured from the edge of the source model-county cropland base). Model values for ‘edge’

physical land limits and specified “willingness-to-accept” manure.

counties, or those that straddle the watershed boundary, are apportioned based on the share of crop and pastureland within the watershed to account for manure flows at the basin level.

The optimization model is designed to minimize the regional cost of applying manure, subject to total manure produced, land availability for manure applications, and other disposal options. The model allocates manure flows across the watershed and neighboring sink counties to minimize the objective function expression:

$$(1) \quad \sum_{ct} \sum_{ct2} [HAC_{ct,ct2} + INC_{ct2} + NM1_{ct} + NM2_{ct2} + ELA_{ct} - FS_{ct2}]$$

Costs include manure hauling and application costs (HAC), land incorporation costs (INC), and nutrient management plan charges for source (NM1) and destination (NM2) counties. A penalty cost for manure levels exceeding land application (ELA) capacity is included to ensure that all manure is land applied subject to available land (this cost is removed from reported costs). Aggregate costs are further adjusted to reflect cost savings from reduced purchase and application costs for chemical fertilizers (FS).

In-county and out-of-county transfers of manure are the primary activities in the model. Potential county-to-county transfers were developed based on an assumed maximum radial distance of either 60 kilometers (37 miles) or 150 kilometers (93 miles), measured from the outer edge of the source county's cropland base. There are 4,060 county-level transfer possibilities in the full watershed model, including in-county and out-of-county transfer combinations. Manure transfers are further disaggregated by subcounty grid location, manure system type, and distance interval, resulting in over 300,000 transfer alternatives.

The primary decision variables in the model represent the quantity of manure transferred, acres used for manure spreading, and manure hauling distance. Model equations include (1) balance equations that track stocks and flows of manure and manure nutrients, (2) constraints on land availability, distribution of confined animal farms (manure sources), and manure nutrient use, and (3) cost accounting equations. In general, wet manure quantities form the basis of model hauling and application costs, while manure nutrient content and uptake rates determine the volume and direction of manure flows.

Manure application rate is estimated for each individual in-county and out-of-county transfer, based on: (1) average nutrient content of manure from the source county (*ct*); (2) average nutrient removal rates for N and P in the destination county (*ct2*), weighted across cropland and pastureland for each of three farm types (non-animal farms, non-confined animal farms, and confined livestock farms); (3) nitrogen volatization factors, with and without incorporation; and 4) the nutrient standard in effect.[3] Data specification by county and farm type allows the model to capture potential variation in assimilative capacity due to differences in cropping pattern, land in pasture, and crop yield.

Equation specifications are provided for two components of the objective function—incorporation cost and fertilizer savings. These measures are particularly important to this analysis, as they underlie differences in model results reported for the annual P standard and multi-year P standard. For a full discussion of the model equation system, see Ribaudo et. al., 2003.

$$(2)\quad INC_{ct2} = (C3 * SH\_I_{ct2} * (AC\_ONF_{ct2} + \sum_{ct} AC\_SPR_{ct,ct2}) * SH\_C_{ct2})$$

[3] Manure application rates may be modified to reflect adjustments in nutrient content (i.e., due to changes in feed supplements or animal mix) and nutrient uptake rates (i.e., due to changes in cropping patterns or yields), as well as county-level acreage shares by nutrient standard, for cropland and pastureland.

Incorporation costs (INC) are computed on an acreage basis, reflecting the per acre incorporation cost (C3), share of acres incorporating (SH_I), total acres using manure—both onfarm (AC_ONF) and off-farm (AC_SPR), and share of acres in cropland (as manure is not generally incorporated on pastureland).

$$(3) \quad FSV_{ct2,N} = (PR_{N} * (N\_ONF_{ct,ct2,N} + \sum_{ct} N\_TRN_{ct,ct2,N}))$$

$$+ (PR_{P} * (P\_ONF_{ct,ct2,P} + \sum_{ct} P\_TRN_{ct,ct2,P}) * PN_{ct2})$$

$$+ (C\_AP * (AC\_ONF_{ct2} + \sum_{ct} AC\_SPR_{ct,ct2}))$$

Fertilizer cost savings (FSV) are calculated differently depending on the nutrient standard in effect. In Equation (3), savings calculated under an N standard include reduced chemical fertilizer purchases and reduced chemical application costs. Savings from reduced fertilizer purchases are computed based on the price (PR) of nitrogen (*N*) and phosphorus (*P*), and the quantity of manure nutrient offset. The nutrient offset reflects use of manure N onfarm (N_ONF) and off-farm (N_TRN), and use of manure P onfarm (P_ONF) and off-farm (P_TRN) —adjusted to capture that portion of P (PN) that is beneficially used by the crop, or the ratio of applied manure at an annual P standard to applied manure under an N standard. Savings from reduced chemical application costs reflects the per acre cost of chemical application (C_AP) and total acres receiving manure under an N standard.

$$(4) \quad FSV_{ct2,P} = (PR_{N} * (N\_ONF_{ct,ct2,N} + \sum_{ct} N\_TRN_{ct,ct2,N}))$$

$$+ \ (PR_P \ * \ (P\_ONF_{ct,ct2,P} + \sum_{ct} P\_TRN_{ct,ct2,P}))$$

In Equation (4), savings calculated under an annual P standard reflect the value of the manure nutrient offset only. There are no savings in chemical application costs (chemical fertilizer application is still required), as manure-N is insufficient to meet full crop needs.[4]

$$(5) \quad FSV_{ct2,P*} = (\ PR_N \ * \ (N\_ONF_{ct,ct2,N} + \sum_{ct} N\_TRN_{ct,ct2,N})\ )$$

$$+ \ (\ PR_P \ * \ (P\_ONF_{ct,ct2,P} + \sum_{ct} P\_TRN_{ct,ct2,P})\ )$$

$$+ \ (\ C\_AP \ * \ (AC\_ONF_{ct2} + \sum_{ct} AC\_SPR_{ct,ct2}) \ * \ PN_{ct2}\ )$$

In Equation (5), savings are calculated under a multi-year P standard. Savings reflect the full value of the manure nutrient offset, as all applied manure is fully utilized by the crop. Savings also includes a partial reduction in chemical application costs, based on the share of acres treated annually within the multi-year rotation (equivalent to PN).

Results

Aggregate costs of manure land application are estimated for the Chesapeake Bay region by alternative nutrient standard. Costs of meeting an annual P standard, where applied manure P equals annual P uptake, are compared against a multi-year P standard as permitted by NRCS guidelines (Table 2). The N-standard costs are reported for comparison and to provide context for a discussion of alternative implementation strategies for a P standard. Results assume that 60

[4] For purposes of this analysis, it is assumed that chemical nutrients are applied at agronomic rates, that manure nutrients directly offset nutrients obtained from chemical fertilizers, that per acre field application costs are fixed

percent of cropland and pastureland within a given area is available for manure spreading.[5] A more complete assessment of nutrient management costs is found in Ribaudo et al., 2003.

For purposes of this analysis, 'Total Costs' are defined as the aggregate cost of manure hauling, field application, and incorporation, plus selected costs associated with the nutrient management plan (manure testing, soil testing, plan development)[6]. 'Fertilizer Savings', reflecting the value of manure as a source of nutrients, include cost savings from reduced fertilizer purchases and reduced fertilizer application costs[7]. 'Net costs' are defined as 'Total Costs' less 'Fertilizer Savings'.

Under an annual P standard, total costs of manure land application in CBW were estimated at $155 million, roughly $30 million higher than costs estimated for the less stringent N standard. The differential in costs is attributable primarily to additional manure hauling charges, since reduced manure applications require greater acreages and increased hauling distances to access available acreage. Costs for manure application and incorporation are also greater under the P standard. Chemical fertilizer savings were substantial, offsetting from 50 percent of the total costs of land application for nitrogen and 41 percent of the total costs for phosphorus, across N and P scenarios. Net costs decline by roughly $63 million for both N and

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regardless of the level of applied chemical fertilizer, and that producers are not permitted to "bank" phosphorus (over-apply for use in subsequent years) to minimize annual field application costs under the P standard.

5 Under an annual P standard, with current levels of manure use for industrial purposes and model transport distance assumptions, all manure produced within the CBW may be land applied within the basin at a landowner acceptance rate of 60 percent. As acceptance rates decline from 60 percent, an increasing share of manure produced cannot be land applied within the basin within 150 km of the source animal operation.

6 Total costs do not consider manure storage costs, or costs of associated with hauling and processing of manure that is not land applied.

7 Savings in chemical fertilizer were based on nutrient costs of nitrogen and phosphorus in the region's most common commercial form and are sensitive to assumptions on fertilizer prices, forms, and application efficiencies. Only the manure nutrients that could be utilized by crops were assigned value. In meeting an N standard, adequate phosphorus would also be applied and the value of a reduced field operation was credited as "savings." However, nitrogen requirements are not met under a P standard. It was assumed that additional commercial nitrogen would continue to be applied, so the chemical fertilizer savings when meeting a P standard included no savings in field operations.

P standard, attributable largely to reduced fertilizer purchases, and in the case of the N scenario, reduced fertilizer application requirements.

Under a multi-year P standard, the total and net costs are between costs under an N standard and costs under an annual P standard, as expected. The model estimates that *total* costs of land applying manure under a multi-year P standard would decline by $4.05 million (3 percent) relative to the single-year P standard. The reduction is attributable primarily to savings on incorporation. Since the same quantity of manure must be transported virtually the same distance under either specification of the P standard (ie., acres receiving manure are identical), hauling costs do not change across P standard specifications.[8]

The decline in *net* costs of shifting from a single to a multi-year P application is substantially larger than the decline in total costs. The change in net costs was estimated at $16 million or 83 percent of the costs of land applying manure to a P standard with single year applications. Virtually all of the difference between total and net costs is attributable to the savings on field applications of commercial fertilizer. Under the multi-year alternative, savings in field operations that are attributable to manure applications are estimated at $11.9 million in the CBW. These saving accrue because nitrogen in manure is used to offset commercial nitrogen fertilizer under the comprehensive nutrient management planning process. When manure is applied at a level that satisfies the nitrogen needs of the crop, phosphorus needs are also generally met due to the nature of the nitrogen/phosphorus ratio in manure, and there is no need to apply commercial P fertilizer to the crop. When manure is applied at a rate based on single-year phosphorus needs—as in the case of the annual P standard—not enough nitrogen will be

8 Under an alternative specification of the model in which land application costs are based on area, cost adjustments would need to be made for the higher application rates, and costs would not decline proportionally to incorporation costs adjustments if costs decline at all.

supplied and additional commercial fertilizer will be needed. (The model did not estimate the costs of commercial fertilizer, since it was assumed that these expenses are now occurring, and increasing manure use only reduces the need to purchase chemical fertilizers.)

Implications of selected study assumptions

As in any study, results are a function of the underlying methods and assumptions. This study makes several key assumptions regarding manure use, cost calculations, and effect of multi-year applications which influence the reported results.

First, the model assumes that cropland is fertilized, and that manure-nutrients provide a direct offset of fertilizer nutrients. Thus, fertilizer purchases are reduced by the amount of manure nutrients provided, and fertilizer application costs are eliminated where manure-nutrients are sufficient to meet full crop requirements. In fact, there is currently little data on the current level of substitution of manure for chemical fertilizer. While a CNMP specifies reductions in commercial/chemical fertilizer requirements, many producers accepting manure may be reluctant to forego chemical applications due to variable nutrient content of manure, concerns for timing of application, and micro-nutrient needs. Moreover, permitting authorities may provide for additional chemical use to ensure adequate nutrient requirements. A reduction in fertilizer cost savings implied will have the effect of reducing the cost differential between an annual P standard and a multi-year P standard.

Soil-P concentrations are influenced by soil type and the nature of farm activities on the land. The distribution of soils eligible for alternative nutrient standards is not currently known, and will most certainly affect potential costs of manure land application. The analysis implies that regional costs may be assessed for each of the three nutrient standard specifications, and the regional gains may be realized, in particular, in moving from an annual P to multi-year P standard. However, many fields may be restricted as to the quantity of manure that can be agronomically applied. Where soil-P is high or nutrient runoff potential high, applied manure may be restricted to annual P requirements, or manure use may be restricted altogether. An accurate distribution of acres qualifying for multi-year P applications is not well documented due to a lack of comprehensive soil-testing data.

Higher manure-P application rates under the multi-year P standard imply a somewhat increased risk of field runoff. Implementation of multi-year P applications may involve a higher degree of field management, including incorporation, to minimize the risks to water quality. Our results assume a constant share of state-level acreage using incorporation—and savings from reduced incorporation costs relative to an annual P standard—which may understate the actual level of incorporation required. Reduced savings from higher rates of incorporation may offset potential savings reported here.

Previous ERS research indicates that landowner willingness to accept manure is an important policy variable in assessing costs of manure land application (Ribaudo et. al., 2003). While our results reflect an assumed rate of 60 percent, actual rates of acceptance are unclear and likely to vary by location and crop type. Lower levels of manure acceptance would increase the costs of manure land application by increasing hauling costs required to access sufficient land.

Summary

Management of animal waste is an important issue in the Chesapeake Bay watershed given the concentration of animal production in areas of the basin and the major State and Federal commitment to the protection of the Bay's resources. New policies governing manure handling are likely to have a significant impact on the animal sector. This is particularly true in the CBW, where counties with concentrations of animal production rank among the highest in the nation in terms of excess manure nutrients per spreadable area off the farm.

The regional modeling framework, combining farm-level Census data with GIS spatial data coverages, provides a framework for evaluating potential animal sector impacts from regulations on manure land application. The model results suggest that alternative implementation strategies for nutrient standards can have an important bearing on producer costs through potential differences in application rates, acres treated, and costs associated with handling commercial fertilizer.

NRCS permits implemention of a multi-year P standard under most soil conditions. Our findings suggest that the multi-year P standard potentially provides a significant savings relative to an annual P standard in areas where land for spreading is relatively scarce. Net costs of manure land application for the CBW totaled $76 million under a multi-year P standard, compared with $92 million under an annual P standard, a savings of 17 percent. The potential savings may help to offset costs incurred by the sector from new federal regulations and policies for land application. Where spreadable land is more readily available, the savings (and costs) would not be as great.

The size of the fertilizer savings offset, representing nearly half of total costs of manure land application under a multi-year P standard, underscores the need to recognize manure as a valued production input within a comprehensive nutrient management plan. Acceptance rates of manure land application will depend in part on actual cost savings that can be achieved through proper management and applications of the manure resource.

The results presented here provide an initial indication of the costs of meeting nutrient standards, and of the range of potential cost savings under the NRCS multi-year P standard relative to an annual P standard. However, actual cost savings at the regional level are sensitive to assumptions on the share of acreage constrained by soil phosphorus concentration, baseline use of chemical fertilizers, and adjustments in fertilizer purchase and application. More research is needed on the implementation of nutrient standards to more accurately assess sector costs and mitigation measures.

Figure 1. The Chesapeake Bay Watershed

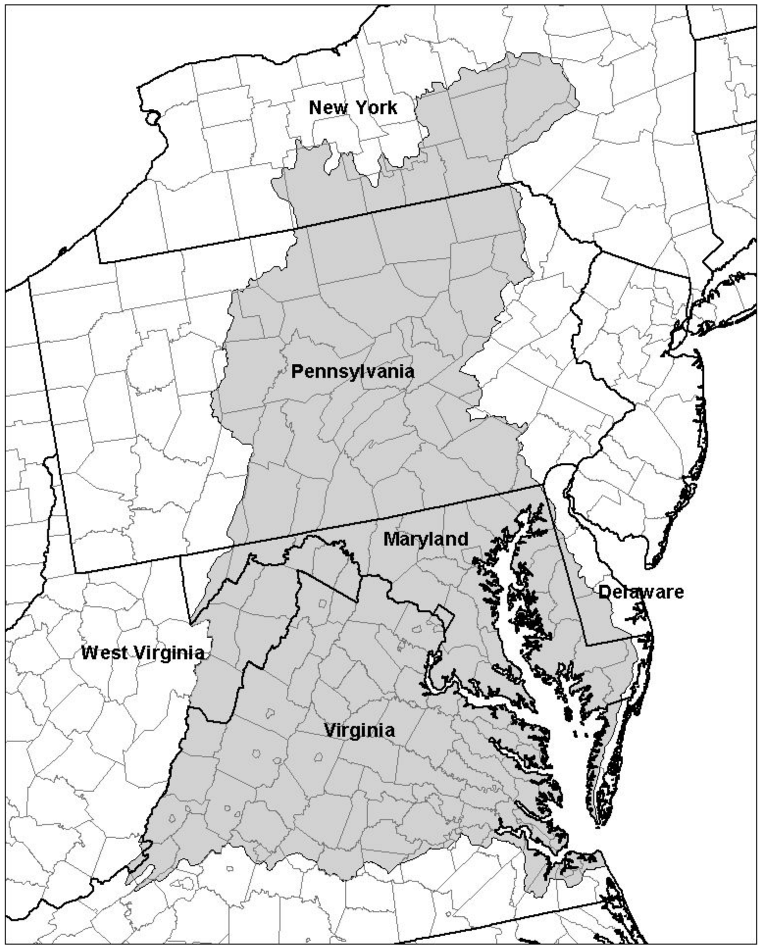

Table 1. Attributes and Cost Factors by Nutrient Standard			
	Nutrient Standard		
Item	**Nitrogen**	**Phosphorus with multi-year application**	**Phosphorus with annual application**
Manure application rate	Based on crop's annual N uptake	Based on crop's annual N uptake	Based on crop's annual P uptake
Manure application frequency	Annually	Once in a multi-year period determined by the number of years of P applied with the manure application	Annually
Acres receiving manure over a rotation	Acres based on N application rate	Acres based on P application rate	Acres based on P application rate
Acres treated with manure in any one year	Acres based on N application rate	Acres based on N application rate	Acres based on P application rate
Cost of manure transport	Function of distance to find adequate land at an N rate	Function of distance to find adequate land at a P rate	Function of distance to find adequate land at a P rate
Cost of manure application to land	Costs are assumed here to be tonnage based and are thus the same across nutrient standards.		
Cost of manure incorporation (applies only on a share of the land receiving manure)	Acres treated based on N application rate	Acres treated based on N application rate	Acres treated based on P application rate
Fertilizer cost savings: From reduced purchase of commercial fertilizer	All manure-N is used by crop Part of manure-P is used by crop	All manure-N is used (fertilizer N needed in non-treatment years) All manure-P is used	All manure-N is used (supplemental N fertilizer needed) All manure-P is used
Fertilizer cost savings: From reduced use of machinery to apply commercial fertilizer	All acres receiving manure (full nutrient requirements met; no additional fertilizer acquired)	Partial acres receiving manure (full nutrient needs met on acres treated; fertilizer required in non-treatment years)	None (fail to meet N requirements with manure applied)

Table 2. Costs of land disposal of manure under alternative nutrient standards specifications in the CBW (60 percent of land assumed available)					
Farm-operator behavioral assumption and cost item	**Cost basis**	**Units**	**Nutrient Standard**		
			Nitrogen	Phosphorus, multi-year application	Phosphorus, annual application
Manure management planning costs	Farm	$ million	10.44	11.24	11.24
Manure transport costs	ton-mile	$ million	81.33	103.72	103.72
Manure application costs	Ton	$ million	28.71	32.12	32.12
Manure incorporation costs	Acre	$ million	4.36	4.36	8.41
Total Costs			124.84	151.44	155.49
Less: Savings on fertilizer from increased use of manure nutrients	nutrient value	$ million	50.77	63.09	63.09
Less: Savings on field application of commercial fertilizer	Acre	$ million	11.93	11.93	0
NET COSTS			62.14	76.42	92.40

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